Art. X.—*On Lightning Conductors.*

By Professor Kernot.

[Read 12th August, 1886.]

A properly constructed lightning-conductor acts in two different ways.

1st. It gradually and silently draws the electricity away from the clouds in the same way as a pointed wire in communication with the earth draws, or, as it is sometimes expressed, *sucks* the electricity away from the charged conductor of an ordinary frictional electrical machine. Every conductor that acts in this way is a public benefit, mitigating the severity of thunderstorms in the locality where it is situated. Hence it would be a perfectly reasonable and proper thing to erect conductors at the public expense upon all lofty buildings or other elevated points in the vicinity of a town. The effect of a single conductor would probably be imperceptible, or nearly so, in this respect; but the effect of a score or a hundred would be manifest in a marked diminution in the intensity of atmospheric electric phenomena over or to the leeward of the place where they were situated. In order to be efficient for this purpose a conductor should—first, be provided with one or more fine, sharp points at its upper termination; second, have its own electric resistance small; third, have a good earth connection.

2nd. When the building is actually struck by lightning, the conductor may be of great use by attracting the discharge to itself and away from other parts of the structure, and conveying it harmlessly to the earth. For this purpose it should—first, be so prominent as to necessarily receive the electric spark, no matter from what direction the electrified cloud travels; second, be of such sectional area as to convey the largest discharge likely to occur without being heated to such an extent as to fuse or become distorted; third, have its own resistance and that of its earth connection distinctly smaller than that of any water-pipe, gas-pipe, or other conducting mass in its vicinity.

In addition to the above, it is a wise precaution to connect the conductor with all the principal metallic masses in the building, to place it on the side of the building most likely to be moistened by rain, and, as far as possible, so to arrange it that any considerable charge of electricity in or upon any part of the building may be, so to speak, drained away as easily as possible. If these last requirements be attended to, little or no harm will result, even though the lightning should in the first case strike a part of the building some distance from the conductor.

Several years ago the Meteorological Society of England invited the co-operation of the Royal Institute of British Architects, the Physical Society, and the Society of Telegraph Engineers in a conference upon lightning conductors. The last-named societies responded to the invitation, and a number of delegates were appointed, amongst whom were Messrs. Latimer Clark, Preece, Ayrton, and Hughes, gentlemen whose eminence in the electrical world is unquestioned. The conference collected all accessible evidence, discussed the same at numerous sittings during the years 1878, 1879, 1880, 1881, and ultimately published a most valuable report, accompanied by a code of rules, for the construction and erection of conductors, together with replies to questions that had been widely circulated as to damage by lightning and efficiency of conductors.

Through the kindness of G. Watson, Esq., architect, Public Works Department, I am enabled to submit this valuable, but, unfortunately, little-known report, to the Royal Society of Victoria.

The code of rules is as follows:—

RULES.

1. Points.—The point of the upper terminal should not be sharp, not sharper than a cone of which the height is equal to the radius of the base; but a foot lower down a copper ring should be screwed and soldered on to the upper terminal, in which ring should be fixed three or four sharp copper points, each about six inches long. It is desirable that these points be so platinised, gilded, or nickel-plated as to resist oxidation.

2. Upper Terminals.—The number of conductors or points to be specified will depend upon the size of the building, the material of which it is constructed, and the comparative height of the several parts. No general rule can be given for this, but the architect must be guided by the

directions given at pp. 12 to 14.* He must, however, bear in mind that even ordinary chimney stacks, when exposed, should be protected by short terminals connected to the nearest rod, inasmuch as accidents often occur owing to the good conducting power of the heated air and soot in a chimney.

3. INSULATORS.—The rod is not to be kept from the building by glass or other insulators, but attached to it by metal fastenings. (See p. 11†).

4. FIXING.—Rods should preferentially be taken down the side of the building which is most exposed to rain. They should be held firmly, but the holdfasts should not be driven in so tightly as to pinch the rod, or prevent the contraction and expansion produced by changes of temperature.

5. FACTORY CHIMNEYS.—These should have a copper band round the top, and stout sharp copper points, each about 1 foot long, at intervals of 2 or 3 feet throughout the circumference, and the rod should be connected with all bands and metallic masses in or near the chimney. Oxidation of the points must be carefully guarded against.

6. ORNAMENTAL IRONWORK.—All vanes, finials, ridge ironwork, &c., should be connected with the conductor, and it is not absolutely necessary to use any other point than that afforded by such ornamental ironwork, provided the connection be perfect, and the mass of ironwork considerable. As, however, there is risk of derangement through repairs, it is safer to have an independent upper terminal.

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* Considerable difference of opinion has existed as to the area protected by each conductor. The latest French instructions, quoted on p. 13 of the Report accompanying the Code of Rules, say a point will "effectively protect a cone having the point for its apex and a base whose radius is 1·75 of its height." The English War Department instructions say that "no precise limit can be fixed to the protecting power of conductors. In England the base of the protected cone is usually assumed to have a radius equal to the height from the ground; but, though this may be sufficiently correct for practical purposes, it cannot always be relied upon."

† Page 11 of Report: "The evidence against the use of glass or other material in order to insulate the conductor is overwhelming, and insulation may be regarded as unnecessary and mischievous. The essentials are—(1) That the rod be attached to the building by fastenings of the same metal as itself; (2) that the fastenings be of adequate strength; (3) that they be of such a form as not to compress or distort the rod; (4) that they allow for expansion and contraction; (5) that they hold it firmly enough to prevent all the weight falling on any one bearing."

7. Material for Rod.—Copper, weighing not less than 6 oz. per foot run, and the conductivity of which is not less than 90 per cent. of that of pure copper, either in the form of tape or rope of stout wires, no individual wire being less than No. 12 B.W.G. Iron may be used, but should not weigh less than $2\frac{1}{4}$ lbs. per foot run.

8. Joints.—Although electricity of high tension will jump across bad joints, they diminish the efficiency of the conductor; therefore every joint, besides being well cleaned, screwed, scarfed or riveted, should be thoroughly soldered.

9. Protection.—Copper rods to the height of 10 feet above the ground should be protected from injury and theft by being enclosed in an iron pipe reaching some distance into the ground.

10. Painting.—Iron rods, whether galvanised or not, should be painted; copper ones may be painted or not according to architectural requirements.

11. Curvature.—The rod should not be bent abruptly round sharp corners. In no case should the length of the rod between two points be more than half as long again as the straight line joining them. Where a string course or other projecting stone work will admit of it, the rod may be carried straight through, instead of round the projection. In such a case the hole should be large enough to allow the conductor to pass freely and allow for expansion.

12. Extensive Masses of Metal.—As far as practicable it is desirable that the conductor be connected to extensive masses of metal, such as hot-water pipes, &c., both internal and external; but it should be kept away from all soft metal pipes, and from internal gas pipes of every kind.* Church bells inside well-protected spires need not be connected.

13. Earth Connection.—It is essential that the lower extremity of the conductor be buried in permanently damp soil; hence proximity to rain-water pipes and to drains is desirable. It is a very good plan to make the conductor bifurcate close below the surface of the ground, and adopt two of the following methods for securing the escape of the lightning to the earth. A strip of copper tape may be led

* It is recommended that the inlet and outlet pipes of large gas-meters be electrically connected together independently of the meter. The absence of this precaution has led to accidents in two very remarkable cases.

from the bottom of the rod to the nearest gas or water *main*, not merely to a lead pipe, and be soldered to it; or a tape may be soldered to a sheet of copper 3 feet x 3 feet, and $\frac{1}{16}$ inch thick, buried in permanently wet earth, and surrounded by cinders or coke; or many yards of the tape may be laid in a trench filled with coke, taking care that the surfaces of copper are, as in the previous cases, not less than 18 square feet. Where iron is used for the rod a galvanised iron plate of similar dimensions should be employed.

14. Inspection.—Before giving his final certificate, the architect should have the conductor satisfactorily examined and tested by a qualified person, as injury to it often occurs up to the latest period of the works from accidental causes, and often from the carelessness of workmen.

15. Collieries.—Undoubted evidence exists of the explosion of firedamp in collieries, through sparks from atmospheric electricity being led into the mine by the wire ropes of the shaft and the iron rails of the galleries. Hence the headgear of all shafts should be protected by proper lightning-conductors.

(Signed)

W. Grylls Adams.
W. E. Ayrton.
Latimer Clark.
E. E. Dymond.
C. Carey Foster.
D. E. Hughes.
T. Hayter Lewis.
W. H. Preece.
G. J. Symons.
John Whichcord.

A careful inspection of lightning conductors upon numerous public and private buildings in Melbourne reveals endless departures from the preceding rules, and leads to the conclusion that, as generally applied here, conductors are rarely as efficient as they might and ought to be, while in not a few cases they are so bad as to be a positive source of danger. The principal faults that have come under my notice are:—

1st. Blunt points. These impair the action of the conductor in silently discharging the atmospheric electricity.

2nd. Insufficient elevation above the rest of the building. In this case the building may be struck at points distant from the conductor. A common case is that of a roof 50 or 100 feet long, with a conductor at one or both ends not rising more than 5 feet above the ridge.

3rd. Numerous joints breaking the metallic continuity of the conductor. These joints may appear mechanically good, but be very defective electrically, especially when old and corroded. They impede the silent discharge, and increase the risk, in the event of actual stroke, of the electricity leaving the conductor and striking across to some other metallic mass.

4th. Insufficient sectional area. This is a most usual fault. Should such conductors be actually struck, they would fuse before the charge was carried off, leaving the remainder to force its way to some other conducting body. Many of our conductors are not more than one-third as large as they should be.

5th. Insulation. Instead of bringing the conductor into the closest contact with the building, many persons carefully insulate it. This in no way aids the conductor in fulfilling its functions, while it greatly enhances the danger should some other part of the building first receive the discharge.

6th. Bad earth connection. This is a common and most fatal defect. Owing to accidental damage, theft, or corrosion, many conductors do not reach the ground at all, but terminate a few feet above. These are most dangerous. They induce the discharge which otherwise would probably not have taken place, and cause a violent manifestation of electric energy at a place where it is likely to do much damage to life or property. Such a conductor should be either properly repaired or entirely removed. Further, some conductors which apparently reach the earth are so terminated that the resistance to the passage of electricity is greater than that of some water or gas-pipe in the vicinity. In this case a lateral discharge is likely to take place, with disastrous results, damaging brickwork or masonry, fusing gas-pipes and setting fire to the gas, or injuring or killing any person in the vicinity.

I do not wish to be an alarmist, but I feel it my duty to point out the extremely unsatisfactory state of the vast majority of lightning conductors in Melbourne, and to urge that a general inspection and renovation should take place under the direction of a competent electrician, who should